

Mathematics and At-Risk Adult Learners: Would Technology Help?

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Abstract

In this paper, we examine the effects of computer-assisted instruction (CAI) on adult at-risk learners in fundamental mathematics education. This examination includes comparing the results of adult learners experiencing learning with CAI with those who do not. Further, we explore and present viable teaching and learning strategies for at-risk students with a focus on a Web-based approach. Both qualitative and quantitative methods are applied to explore the effect of CAI on adult at-risk learners. The analysis of the data suggests not only a positive effect of CAI on student learning of mathematics, but also concerns and issues arising from the learning experience.

INTRODUCTION

“Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students’ learning” (National Council of Teachers of Mathematics [NCTM], 2000, p. 11). This underscores the new trend in education that emphasizes the importance of learning with technology instead of learning from technology (Jonassen, Howland, Moore, & Marra, 2003).

Inherent in this is an increased demand on the integrated model of learning in mathematics education. That is, technology needs to be appropriately integrated into student regular mathematic learning. This challenges not only regular school mathematics, but also mathematics education for struggling, at-risk learners. The trend in providing computer-assisted instruction to at-risk learners has evolved from providing learning assistives to improving educational performance with better instructional technology and design strategies (Edyburn, 2003).

Within this population of at-risk learners are adult learners. It is argued that at-risk adult learners can benefit from the support of technology in the way of computer-assisted instruction (Learning Disabilities Association of Canada [LDAC], 1999). To date, however, very few studies have been conducted on at-risk adult learners and the assistance of technology (Nicol & Anderson, 2000). Further, opportunities for using such contemporary learning methods seem limited to mainstream education (Brown, 2000). This calls for studies to investigate technology on improving achievement of at-risk adults to determine its effect, and to further improve this method of instruction.

In this paper, we examine the effects of computer-assisted instruction (CAI) on adult at-risk learners in fundamental mathematics education. We use CAI such as tutorials or simulation activities as supplements to teacher-directed instruction. In other words, CAI is used in the context of this study to indicate a

blended approach of instruction using technology and classroom-based learning. Our examination includes comparison of the results of adult learners experiencing CAI with those who do not.

REVIEW OF RELATED LITERATURE

In this study, at-risk learners are seen as those with some type of learning barrier, such as learning disabilities, low literacy rates, language barriers, and/or life struggles. In particular, these students often fail academic courses factored by family socioeconomic conditions, family instability or tragedy, or having a sibling who drops out of school. At-risk students experience at least one of these factors, putting them at risk of not completing high school or attending college (Price, Field, & Patton, 2003; Splittgerber & Allen, 1996). Within this at-risk group, students with learning disabilities struggle with genetic and/or neurological factors or injury. These learning disabilities impair students' cognitive processes such as perceiving, thinking, remembering, or learning—and affect one in ten Canadians, or three million people (Learning Disabilities Association of Canada [LDAC], 2002). In the United States, there are an alarming number of at-risk learners in both junior and senior high schools, accounting for about half of the students (Splittgerber & Allen, 1996).

We recognize that learning-disabled students may have quite different characteristics from other at-risk learners. However, as stated by Barron (1989), "It is extremely difficult to define who is at-risk and who is not because being at risk is not related to a single cause, but rather to what Mann (1986) refers to as a 'nesting of antecedent problems'" (p. 2). The participants of this study have not been officially coded or tested for their cognitive deficiencies, but they have been recognized as at-risk learners who have not completed their secondary education due to various barriers. The unclear cognitive state of the participants, therefore, makes it impossible to differentiate learning disabilities from other learning risks. We believe, however, a study on this type of learner can shed light on research for such a student population and related intervention programs. A literature review on both at-risk learners and those with learning disabilities provides a foundation for this work.

Both the BC Ministry of Education (2002) and The Meighen Centre for Learning Assistance and Research for Mount Allison University (1996) point out learners with learning disabilities need intense direct instruction. They also need instruction with compensatory strategies. They argue that the best approach to teaching learning disabled students is with remedial, corrective skill-building instruction, supplemented with ample explanations and examples. This can be supported with modified curriculum by using alternate instructional and evaluation strategies. They further suggest that the use of equipment, including computer and audiovisual technology, is a good choice in compensating for learning barriers.

As well, the Learning Disabilities Association of Canada [LDAC] (1999) endorses technology as a viable learning tool with its multimedia approaches and assistive tools. Advantages are the opportunity to learn basic skills through technical tools, gain instant feedback, revisit material frequently, control the

learning pace, and employ the use of assistive technology devices (Riley, Kunin, Smith, & Roberts, 1996). Johnson and Hegarty (2003), in their study with adult learners who had mild to moderate learning disabilities, found that technology, through the use of the Internet, enabled practice and development of skills in literacy. Students were more likely to concentrate, participate, and converse through this venue. As well, Lewis (1997) studied and concluded that technology benefited students with disabilities through improved delivery of instruction, improved student attitude, compensation for the effects of disabilities, and increased student learning. Avitabile (1996) concluded from his study with at-risk high school students, "The overall change in student attitudes reinforces my belief that students can learn content and are more confident when they develop computer applications where they can implement their own ideas" (p. 25). He found the best use of computer applications for this population was those that blended sound, graphics, animation, and text.

A study by Nicol and Anderson (2000) reports an experiment that compared computer-assisted instruction with teacher-led instruction. Using adult learners with mild learning disabilities, they supplemented traditional learning of numeracy with computer-assisted instruction (CAI) to determine its educational value. They found that students with mild and moderate learning disabilities fared just as well with CAI as with conventional instruction. This showed that educational technology in the form of CAI does not negatively affect learning. They identified key contributors when using CAI as individualized instruction sequences, learner response control, quick and individualized feedback, and motivation-enhancing game-like activities. Most notably, students were found to deliver quicker and more accurate answers due to automaticity from the extended practice of basic mathematics skills.

As a benefit, it is found that CAI enables a more appropriate use of scaffolding for individual student learning, particularly learners with learning difficulties, as tasks can be divided into appropriate learning steps. Learners can engage in concept presentation, relevant examples, and interactive exercises with hints and immediate feedback. Using CAI, they can read, try, and review the content as long as and as often as they want (Li & Edmonds, 2004). Supporting this, Hornbeck (1990) shares how CAI can empower at-risk students who normally feel a lack of control over their lives, as they take control over their learning through technology. More so, he comments that not only can CAI help build basic skills, such as reading and mathematics, but it can also help students with critical thinking and problem solving. Technologies in general, he concludes, help to enhance at-risk students' motivation, interaction and learning.

However, some challenges remain with this educational approach. The concerns in using technology with learning disabilities includes encountering reading difficulties, accessibility problems, technical problems, and digital dividing (Johnson & Hegarty, 2003; Moll, 1997). Additionally, there is an ongoing debate in the choosing of appropriate instructional strategies for struggling learners using technology. Some prefer to use drill and practice activities, thereby enforcing the learning of foundational facts and knowledge

(Donovan, Bransford, & Pellegrino, 1999; LDAC, 1999). Others, however, suggest bypassing rudimentary levels of education to develop a richer, interactive environment using technology that encourages higher-order thinking and motivation (Brown, 2000; Lewis, 1997; Nicol & Anderson, 2000; Riley et al., 1996). A third view believes that learning should be offered in two levels: first, a focus on skill building with reinforcing corrective learning (BC Ministry, 2002), and then empowered with problem-based approaches (Jonassen, 1999). That is, after learners succeed in understanding a basic concept, they can engage in meaningful and practical exercises that develop their understanding (Li & Edmonds, 2004). Echoing this, Jitendra and Xin (1997) suggest that at-risk students first master basic computer skills before engaging in more complex tasks such as problem solving.

Taken as a whole, educators must consider that those with learning disabilities may be lacking perception, understanding, and processing abilities, and special care should be taken in selecting teaching and learning strategies for them (LDAC, 2001). Strategies should include offering a consistent and structured approach to learning, providing frequent positive feedback, and offering a variety of text and visual materials. More so, the way learning is structured has an effect. For example, the LDAC encourages teachers to provide small sequenced tasks, well organized learning, and allow for drill and repetition, leading to the mastery of skills. However, to ensure learning is successful, prerequisite skills, if missing, first must be taught in the same manner.

Taking note of the concerns, as well as the benefits of CAI, informed our design approach of a learning environment with technology for at-risk students. This will be reviewed in the discussion and recommendations section.

THEORETICAL FRAMEWORK

The theoretical framework used in building the computer-assisted instruction in this study for at-risk learners is a blend of learning theories derived from cognitive and behavioural psychology. We have found that the principles of behavioural theory and cognitive theory work well together for an at-risk population. Both of these theoretical frameworks offer perspectives that are important, and each tells half the story of student behaviour and needs.

Behavioural theories of instruction consider student learning behaviours as predictable. That is, the link between stimulus and response are predicted when designing instruction (Winn, 2004). For instance, behavioural theorists such as Gagne present instructional design models that focus on mastering a skill by first identifying sub-skills and the strategies needed to learn each one individually. Then, through aggregating this knowledge, they assume the student will be able to perform the final skill. Cognitive theorists point out complex factors that mediate between stimulus and response, such as individual mental processes. For example, some students see and respond to stimulus differently than others. Therefore, understanding this individuality is important when designing learning (Winn, 2004). Instructional designers and teachers need to consider both theories. In doing so, they can manage mastery learning, while at the same time be open to diverse learning styles and different student outcomes.

Supporting this blended approach, Jonassen, Mayes, and McAleese (1993) state with introductory learning, as primarily experienced by at-risk learners, very little prior knowledge is present. Such students are at initial stages of schema development calling for traditional instructional approaches. This encourages the team to lean towards behavioural instructional theory when designing learning activities. After this stage of learning, Jonassen et al. state that learners enter an advanced knowledge acquisition stage (and later to a level of expertise) that focuses on solving complex and context-rich problems. This calls for a constructivist approach to the curriculum. This blended approach to learning is echoed by Roblyer and Edwards (2000). They add that teachers use directed instruction to help student acquire skills, and employ other motivating methods such as collaboration, to catch learners' interest and aid them in transferring their learning to genuine problems. They share a quote from Tinker (1998), who warns "Thinking that traditional content is less important than learning to learn ... is a dangerous doctrine" (p. 52). Based on these theoretical approaches, we designed instruction that builds mastery in skills and knowledge as an initial stage of learning, and then moves towards more authentic activities, such as problem solving.

Bloom's (1971) model, based on his Learning for Mastery theory, provided practical guidelines for our design of the initial stage of learning. This model breaks down learning into incremental units of instruction infused with frequent testing, and gives students an active role in responding and self-pacing. He points out five criteria for successful use of this model: "having an aptitude for particular kinds of learning; quality of instruction; ability to understand instruction; perseverance; and time allowed for learning" (Winn, 2004, p. 22). Bloom contends that, if given enough time, 95% of all students will gain mastery of a subject. Additionally, he comments that students with low levels of ability and knowledge will gain more from this model of instruction.

Scaffolding is another theoretical aspect that heavily influenced our instructional approach in this study. Scaffolding techniques use learning supports to promote cognitive development. Researchers argue that many tools can be used to "help bring the student up from their level of understanding to a higher level by showing graphic examples and by giving them real-life experiences relevant to their individual needs" (Roblyer & Edwards, 2000, p. 60). In using cognitive principles in a design process, however, it is important to first determine which skills the students possess (Jonassen, 1999). Then, if necessary, cognitive tools, which are "computational devices that can support, guide, and extend the thinking processes of their users" (Jonassen, Peck, & Wilson, 1999, p. 14), can be added to build, or scaffold, the learners' ability to perform the tasks. Cognitive tools can be used to "extends learners' cognitive functioning by engaging learners in thinking while constructing knowledge of which there would not otherwise have been capable" (Jonassen et al., 1999, p. 14).

A concept central to scaffolding is the zone of proximal development. In this concept, Vygotsky envisions a gap between the student's current knowledge base and his or her potential level of ability (Winn, 2004). The support given within the "zone" is vital and lends towards methods of teaching, such as scaffolding.

Activities that aid learners as they move through the zone to a higher level of ability may be hints, models, analogies, or demonstrations. Not only does this cognitively and emotionally support learners, it also gives them courage to move through the learning as their needs are met (Winn, 2004). It is important to recognize scaffolding as a temporary framework to support learners' performances beyond their capabilities.

Considering the two theoretical foundations, we believe that by building learning based on the principles of behaviouralism and cognitivism, educators can provide instruction that is parceled for mastery and individuality at the same time.

PURPOSE AND RESEARCH QUESTIONS

The main purpose of this concurrent mixed methods study is to examine the effects of CAI on levels of achievement by at-risk adults in basic mathematics education. This examination includes comparing the results of adult learners experiencing CAI with those who do not, and converging these findings with qualitative data to help explain effects on achievement. This is a pilot study for a much bigger research project and is conducted to clarify further research questions. Specifically, the following research questions guide the study:

- Do adult learners with learning disabilities improve their level of achievement in mathematics studies by engaging with computer-assisted instruction (CAI)?
- What benefits and advantages emerged when using CAI with at-risk learners?
- What limitations and challenges were identified when using CAI with at-risk learners?

METHODOLOGY

This experimental study uses mixed methods for collecting data, and focuses on behavioural and cognitive outcomes. The primary approach to this study is an experimental model with a case study nested within it (Creswell, 2003). This mixed method approach advocates "one method ... nested within another method to provide insight into different levels or units of analysis," thereby drawing on all possibilities (Tashakkori & Teddlie, as cited in Creswell, 2003). Furthermore, this study's concurrent structure in collecting data simultaneously provides a broader perspective on the phenomena, with the qualitative data helping to describe aspects the quantitative data cannot address (Creswell, 2003).

Participants

The participants in the sample were selected purposively for their unique setting and characteristics as compared to average, mainstream students. It was decided to compare three classrooms of at-risk adult learners studying basic mathematics. The sample was from an adult high school in Western Canada enrolled in an Adult Basic Education (ABE) program. Learners in this sample struggled with learning and academic achievements throughout their life, and had entered a number of learning programs in the past, usually without success.

Treatment groups included Class 1 and Class 2. Class 1 consisted of 22 learners, who ranged from newly immigrated to aging Canadian adults, and with an average age of 25 years old. Of this sample, a large proportion of the students were from different ethnic backgrounds, with approximately 12% being Native and 25% being other ethnic groups. For both these groups, English was their second language. The other ethnic learners were newly immigrated and sought to continue their learning gained from abroad. As well, they hoped to achieve a good use of the English language, and a Canadian High School Diploma.

Class 2 (n=10) also used the particular CAI program designed for this experiment, but were taught by another teacher. The data collected from this class were from the student exit survey only, and these data were merged with those from the first treatment group.

Class 3 was the control group with 16 adult learners. Students from this class were enrolled in the same course as Class 1 and 2, but from a previous term. However, this group did not experience CAI instruction, and instead had traditional teaching in the classroom. See Table 1 for demographics for Class 1 and Class 3.

Table 1: Sample Demographics for Class 1 and Class 3

<i>Variable</i>	<i>Control Group % (N=16)</i>	<i>Treatment Group % (N=22)</i>
Caucasian	45	63
Native	27	12
Other Ethnic	28	25
Female	50	63

Setting

The context of this study is a Canadian Adult Basic Education (ABE) mathematics class that is equivalent to a middle school, grade 8–9 program. The content in the mathematics course was fundamental and reflected the basic nature of the program. In the classroom setting, learners were reintroduced to basic mathematical operations, pre-algebra concepts, and geometrical properties, addressing the need for numeracy skills by helping learners to develop math skills at a functional level with goals to enter higher levels of education. The particular course under study had recently added an online (Web-based) component, thereby creating a blended learning approach. This online component was a Web site designed by the teacher that displayed simple explanations, examples, and interactive exercises for every topic taught in the face-to-face setting (thereafter referred to as the teacher’s Web site). As well, links were added that connected to external Web sites offering mathematical explanations and interactive practice exercises. Both pre- and post-tests delivered online were developed by the teacher and added to the Web site. It is worth noting that the teacher had a graduate level background in educational technology.

For the treatment group (Class 1), students were taken into a computer lab for one hour per week. The mathematics course ran five hours a week for 16 weeks. Thus, students had approximately 15 hours of computer lab time within

the semester, plus whatever time they accessed the Web site outside of class. Tracking records from students' online time showed an average of five additional hours of Web site access for the semester. During the computer lab time, students were directed to the teacher's math Web site.

Data and Instruments

The study used both quantitative and qualitative data to determine how technology affects learning. Both forms of data were collected at the same time, and later integrated to interpret overall results through statistical and text analysis. One of the researchers was the teacher and technologist, performing in a participant-observer role. The other researcher performed as an observer-researcher.

Quantitative data consisted of student data collected from academic tests and surveys. The tests were both online and paper-based. The paper-based tests were a course pre-assessment test, monthly unit tests, and the final examination. The online tests were a monthly pre/post-test that focused on one topic within a unit. In addition, entry and exit surveys were administrated to the treatment group. These surveys included multiple-choice questions and open-ended narratives. Entry surveys focused on learners' computer skills and comfort, while the exit survey asked students about their learning experience with technology.

Student qualitative data consisted of open questions on the entry and exit survey, as described above. Additionally, teacher qualitative data included detailed field observations, and a journal recording her actions, such as lesson plans, redesigning curriculum, and self-reflections. Table 2 gives details on the data collected from students.

Table 2: Methods of Data Collection

Group	Class #	N	Data	
I – Treatment*	1	22	Pre-test	Post-test
			Pre-assessment	Unit tests
			Online quizzes	Final grade
				Exit survey
				Online quizzes
	2	10		Exit survey
II - Control	3	16	Pre-assessment	Unit tests
				Final grades

**Computer-Assisted Instruction*

As for the instruments used, online pre- and post-tests for treatment groups usually included four to five questions per quiz. The first four sets of pre- and post-tests were identical. The last quiz differed slightly between pre- and post-tests. For example, the names used in a word problem, or the quantity of a unit of measure, were changed. However, the format of the questions and the level of difficulty remained the same. As well, each unit test was paper-based and consisted of approximately 40 questions covering all topics taught in the unit. The pre-assessment tests were administrated to each group on the first day of class to determine the prerequisite mathematical skills. Additionally, final assessments were conducted at the end of the course with 85 short-answer questions. Last,

student entry surveys included four multiple-choice questions, and three open-ended questions. The student exit survey had 27 multiple-choice questions, and four open-ended questions. Tables 3 and 4 (pages 152–154) show details of the qualitative and quantitative instruments used, along with the procedures.

Analysis

Quantitative Analysis

Descriptive statistics were used for three separate sets of scores: pre-assessment tests, unit tests, and final grades. A *t*-test was run on each of these sets of scores to determine if there was any significant difference between the mean scores of each group.

Additionally, a *t*-test was performed on scores from a number of online lessons. Pre-test and post-test scores, for Class 1 only, were used to determine if there was any significant difference in their scores before and after learning exclusively online. As well, responses from the exit survey gave statistics on the treatment group (Class 1 and 2) students' feedback on their CAI experience. Pearson's correlation coefficients were used for this.

Qualitative Analysis

All qualitative data were placed into digital form in a word processor, and organized into categories such as objective of the lesson, student reactions, noted impact, problems, and lesson changes for the technology-based class (Goffman, 1959). The researchers analyzed first the data independently, using codes and frames, to identify salient themes. They then compared their analysis, discussed similarities and differences, and developed mutually agreed themes.

Furthermore, triangulating the data provided information to address the research questions. For instance, triangulating the qualitative data with quantitative results helped answer questions about the benefits and challenges of using technology with at-risk students. That is, students' scores were compiled with student reactions to determine what about technology affected their learning. We could then determine what was motivating and affecting the learners as well as identify online design ideas for this population. The qualitative data is presented in themes—such as benefits, challenges, and strategies—and sub-themes—such as increased satisfaction and student confusion with an online format. Illustrations and supporting quotes from participants accompany the sub-themes.

Reliability

Research shows that qualitative data needs to employ techniques to insure reliability and accuracy. These techniques include collecting different forms of data, and from extreme cases, particularly looking for negative evidence (Miles & Huberman, 1994). Hence, we focused our attention not only on the positive effect of CAI in student learning, but also on arising issues and areas of concern. As well, the qualitative data was triangulated with the quantitative data, and analyzed by two reviewers independently.

To test for the reliability of the testing instruments, six correlations were conducted between the final marks and each unit test scores. All the correla-

Table 3: Instrument Details—Quantitative Data

Type of instrument	Number of questions	Question sample	Procedure
Online pre- and post- tests	Average 4–5 questions per quiz. A total of five online quizzes created by the teacher to complement curriculum.	<p>Solve the following division problems with fractions. Click on your answers and SAVE each one before FINISHING the quiz.</p> <p>Question 1 (1 point) Solve: $1/2 \div 1/3$</p> <p>a) $1/6$ b) $2/6$ c) $1\ 1/3$ d) $1\ 1/2$</p>	Each month one unit of mathematics is taught. During this time, students engage with online activities, which include pre- and post-testing of a new topic not taught in the classroom. After the pre-test, they work through a lesson on the topic, which includes explanations, examples and practice. After this online lesson, they attempt the post-test, which is identical to the pre-test except for Unit 5, which has the same level of difficulty and context.
Unit tests	Approximately 40 questions covering all topics taught in each unit.	<p>a) Is 8925 divisible by 2, 3, or 5? b) Write in standard form two hundred million two hundred nine</p>	The unit tests are given monthly after each of the eight units are taught. The units cover whole numbers to equations. Each unit test is paper-based and closed book.

Pre-assessment test	The pre-assessment test comprises 45 multiple-choice questions, and 10 short answer problems.	a) Expand the number 56 1) $(6 \times 100) + (5 \times 10)$ 2) $(5 \times 10) + (6 \times 1)$ 3) $(6 \times 10) + (6 \times 1)$ 4) (5×1)	All students registered for the Adult Basic Mathematics course are given this closed-book pre-assessment test on the first day of class to determine if they need to move to another level.
Final assessment	The final test has 85 short answer questions.	a) Identify each as a prime or composite number: 8, 17, 63 b) Solve the following: $\frac{-5x(-6)+(-14)}{-4}$	The final test is delivered on the last day of class and is a closed-book three-hour exam. It covered all material taught within the semester.
Student Entry Survey—closed questions	Four multiple choice questions	a) What are some of the software programs you can use (use it a little or know it well): e.g., Interview browsers, word processing, etc.	Students are given this survey in the first week of class to determine their computer skill and level of comfort. The consent form for the study was attached to the entry survey.
Student Exit Survey—closed questions	27 multiple choice questions	a) I would rather the teacher do live teaching than learn online: agree, not sure, disagree b) Online features, did they help or not help?: Another way to learn classroom lessons: did help, did not help	On the last week of class, students were given the exit survey. The survey addressed their experience and feelings about learning math with technology.

Table 4: Instrument Details—Qualitative Data

Type of instrument	Number of questions	Question sample	Procedure
Student Entry Survey—open questions	Three open-ended questions	How many hours a week do you spend on the computer?	Students are given this survey in the first week of class to determine their computer skill and level of comfort. The consent form for the study was attached to the entry survey.
Student Exit Survey—open questions	Four open-ended questions	a) What other Web site feature helped you to learn?	On the last week of class, students were given the exit survey. The survey addressed their experience and feelings about learning math with technology.
Researcher Observation notes	Notes were taken for 16 weeks over the entire semester in a note book. The observations were on students reactions during computer use.	Student Reaction (February 19 th , Wed; Lesson: Whole numbers). On a show of hands, the majority enjoyed this way of learning and exercise. A few did not—impatient learners, new to technology.	After each computer class, which was once a week, notes were taken on student reaction to the new lesson online.
Teacher Curriculum changes	During each week of the semester, ideas were recorded on changing current or future lessons delivered online.	Design recommendations: development (February 26 th , Wed; Lesson: Whole numbers). Placing hints in solving may help with learning and activities; select more appropriate materials.	After each computer class, which was once a week, notes were taken on student reaction to the new lesson online.

tions were statistically significant at the .001 level. There were strong correlations among all scores, with the smallest correlation coefficient being .58. This showed that the reliability of each testing instrument was high.

RESULTS

Student Background

To examine students' background, we administered an entry survey to the treatment group ($n=12$) to explore their technical skills, access to technology, and attitudes toward learning with technology. The results showed that 83% had computers at home, with 67% connected to the Internet. We also found that 83% were comfortable enough with computers (i.e., they could turn the computer on, perform basic e-mail tasks, and use common software such as MS Word), and 58% knew the Internet well enough; however, only 25% used computers more than 10 hours per week. Approximately half of the sample knew how to use e-mail, presentation, and word processing software. Yet only 25% felt comfortable using spreadsheet programs, and very little were familiar with Web design software.

In the treatment group, only one student took an online course before entering this class, whereas others had not extensively used computers in other classes. When surveyed on their anticipation to learning with a computer, most (83%) felt they might enjoy it, and saw it as a possible new learning approach that would be helpful and fun. However, two participants were skeptical of using technology in their learning. Of these two, only one stated that she experienced headaches and confusion when using computers. We surmised the students in the treatment group had a basic working knowledge and moderate comfort level with computers.

Quantitative Results

A pre-assessment test administered by the school's mathematics department was given on the first day of class to both treatment and control groups to measure their level of knowledge in mathematics. It was found in a t -test ($t=.305$, $p=.76$) that there was no significant difference between the two groups, and the mean result on the assessment was 67.6% for the control group, and 68.6% for the treatment group. This showed each group had about the same level of mathematics knowledge upon entering the course.

Final grades for both groups were compared in a t -test ($t=1.9$, $p=.066$) and no significant difference was found. The mean grade for the control group was 50.3 ($SD=29.3$), and the treatment group had a mean of 68.3 ($SD=19.2$).

To further explore the effect of CAI on achievement, unit tests (closed-book tests delivered every four weeks in class on varying subjects) were compared between the control and treatment groups. See Table 5 (page 156) for the means and standard deviations.

It was found that there were significant differences in three out of the six unit tests. Those units studied whole numbers, fractions, and decimals. That is, the treatment group scored significantly higher than the control group in all the three units. See Table 6 (page 156) for details.

Table 5: Mean and Standard Deviations for Unit Tests

Unit	Control Group			Treatment Group		
	N	M	SD	N	M	SD
Unit 1 – whole numbers	14	54.8	13.1	14	83	8.5
Unit 2 – fractions	14	56.1	26.7	14	73.7	16.9
Unit 3 – decimals	14	56.6	32.7	14	79.1	10.5
Unit 4 – ratios	11	66	21.6	13	73.1	16.6
Unit 5- integers	10	80.5	18.2	13	87.3	6.9
Unit 6 - equations	10	58.7	28.5	13	71.6	22.5

Table 6: t-test for Unit Tests

	t	p
Unit 1 – whole numbers	6.77	.000*
Unit 2 – fractions	2.09	.047*
Unit 3 – decimals	2.45	.021*
Unit 4 – ratios	.92	.369
Unit 5- integers	1.25	.227
Unit 6 – equations	1.22	.237

* $p < .05$

Additionally, online testing was used to measure the effect of learning completely through technology, and delivered to the treatment group only. A comparison was performed on five pre- and post-tests when instructing specifically with computer-assisted instructions (CAI). In these five lessons, no instruction or pre-lessons was given by the teacher on the concept delivered in the CAI segment, and each online lesson addressed one new concept from a familiar topic. These students learned solely from the online instruction, examples, and interactive practice exercises. Results showed there were significant differences for two out of five lessons. Post-test scores were significantly higher than pre-test scores for the “order of operation” quiz and the “division of fractions” quiz, which were the first two quizzes. See Table 7 for details.

Table 7: t-test for Online Pre- and Post-Tests

Pre-test and Post-test	t	p
order of operations for whole numbers	2.46	.032*
division of fractions	5.59	.000*
solving word problems using decimals	.397	.718
comparing and ordering integers	1.00	.351
analyzing like terms in equations	1.56	.153

* $p < .05$

Through an exit survey, learners provided feedback on their experience with computer-assisted learning. The survey revealed that most students enjoyed working on computers in the lab, though their use at home remained the same as in the beginning of the class. A high percentage (89%) hoped to use computers more in the future. For example, students hoping to use computers more in the future was positively correlated with how helpful the math Web site was in understanding concepts ($r = .541$, $p = .017$), and how effective the interactive quizzes and exercises were to learning ($r = .592$, $p = .008$).

The next issue relates to access. It was reported that 78% of the students accessed the Web site outside of class either from home, or in the school's library. Further, access seemed to have had an effect on students' perception of how much they learned. The frequency of classes to the computer lab was positively correlated with students' feeling that the technology was helpful in their learning ($r=.456$, $p=.049$). The more they visited the computer labs, the more likely students found the Web site helpful in understanding math concepts ($r=.571$, $p=.011$). More specifically, students found that frequent visits to the computer lab were useful as the lab engaged them with extra explanations of math concepts and elements ($r=.456$, $p=.049$). Having access from home was positively correlated with finding the teacher explaining math concepts and giving directions helpful before using the Web site in the computer lab ($r=.505$, $p=.027$).

In summary, all students thought the CAI component helped with their knowledge, and appreciated the guidance and clarity given by the teacher. They also favoured the CAI program's immediate feedback, extra explanations, and examples, as well as the opportunity to extend their learning, practicing, and being quizzed in mathematics. In addition, there was a good response to the design, navigation, and communication tools provided by the CAI. Though the responses were positive, results showed that approximately half the students were still unsure of CAI as an instructional tool.

Qualitative Results

Qualitative analysis was conducted from field observations, student narrative feedback, and the teacher's journal which recorded her actions, reflections, lesson plans, and changes to the curriculum. From the data certain themes emerged that gave rise to the impact of computer-assisted instruction. These themes are discussed from three perspectives: the first part looks at benefits of CAI on student learning of mathematics; the second theme is on effective strategies for delivering CAI learning, and; the third addresses concerns and issues arising from the CAI learning experience.

The Benefits of CAI Learning

Increased confidence level: From the field observation notes and the instructor's reflection, it was evident that those students who were struggling with learning difficulties gradually built up their confidence in this learning process. This confidence reflected not only on their learning of mathematics, but also on their mastery of technology. Once helped with technical and navigational problems, students became familiar with and enjoyed the digital environment. This increased their confidence, and towards the end of the course, most of them were very comfortable using technology to learn and solve problems.

Increased satisfaction: Students' final evaluation and instructor's observation notes and actions showed that students who were involved in computer-assisted instruction showed a higher level of satisfaction than those who were in the traditional class. Overall, they enjoyed the new learning experience and opportunity. They were highly motivated and liked the interactive process:

It was interesting. I guess I never got board [sic] learning online. (AN)

[I liked] the practice quizzes with instant feedback. (LB)

Learning online is an excellent idea because it helps us to clear our doubts [about math]. (ER)

Transformation of knowledge, skill, and ability: It was found that students' knowledge, skill, and ability reflected in face-to-face settings were easily transferable to online environments. There was evidence of reciprocal transferring of skills and knowledge between in-class and online learning. For example, one of the most difficult but important exercises in mathematics is solving situational problems (or word problems). Students in CAI instruction were able to view multiple examples of how to break down word problems by viewing a step-by-step lesson with a mnemonic tool, and later applying their understanding of this method. Online resources allowed the teacher to expand the number of guided examples and exercises in solving problems. Consequently, the students' strengthened ability to apply this to in-class exercises and quizzes was evident compared to the control group.

For the first time, I was taught in such a way that I could understand and enjoy math. [Anonymous]

...we didn't jump from learning one thing to another unit in one week. [Anonymous]

Online and in class complement each other: Our results suggested that the continuity of online and in-class learning helps bridge the possible gap of understanding and enhances learning. Both mediums helped strengthen student learning, which was evident in their work, understanding, and ability in class and online. For example, students showed improved skills in independent learning as well as improved knowledge and analytical skills. This was evident in their class work, whereby students quickly finished and accomplished in-class exercises compared to the control group. Consequently, online learning provided an alternate learning tool by giving a larger range of information and activity, thereby increasing practice and strengthening overall learning. When learning complex concepts, however, more classroom instruction proved to be optimal and even necessary considering the learners' low reading abilities and weak learning skills. As well, a downfall of online learning, with its links to external activity Web sites, is the inconsistency of terminology and the lack of age-appropriate materials. This impedes the learner by confusing them even more. Therefore, we believe that we benefit the most if we consider how learning mathematics education in face-to-face and online settings can complement each other (Li, 2003).

Technology and diverse learners: A large proportion of the students in the treatment group had Native and other Ethnic backgrounds. Having access to the Web site gave those with language barriers, including the Native students,

additional resources to learn concepts. They could read explanations, practice, and test their learning in a self-controlled environment as slowly and as often as they needed. Further, out of all the Native students in both the control and treatment groups, only one successfully finished and passed the course. This student is from the class that used CAI learning.

Effective Strategies for CAI

Scaffolding: It was found that CAI enabled a more appropriate use of scaffolding for individual student learning. This was particularly important for these at-risk adult learners. For example, the tasks were divided into appropriate learning steps, including concept presentation, relevant examples, and interactive exercises with immediate feedback. As well, various hints and prompts were provided in the program so that students could get help when needed. (See Example 1 in the Appendix, page 166.) Using CAI, they could read, try, and review the content as long as, and as many times as, they wanted in a non-threatening environment.

It has as many examples [as] you want so even if you get the wrong answers you can still go until you get correct or until you understand. It also tells you step by step how to do what your learning. (AL)

I liked the Web site of math and all the explanation [sic] that was there. It was very helpful. (LEK)

Visually appealing material: Learners responded well to visually appealing Web pages. For example, care was taken to add contrasting and calm colours, such as purple and white. As well, most Web pages provided graphics such as measuring cups or weighing scales to show mathematical processes or the relevant use of concepts. For more complex mathematical processes, such as dividing fractions, animated graphics were used to show the steps involved, with learners controlling the motion (see Example 2 in the Appendix, page 166). These graphical tools provided helpful learning cues for the students, especially for those with reading difficulties.

Teacher assistance: The findings demonstrated that for these students, it was vital that teachers are available any time they need. Although they were gaining confidence and learning through this new process, they still needed guidance when lost in navigating or understanding. For example, at times, students struggled with uncertainty, technical failure, navigation problems, or lost work. This resulted in the student feeling frustrated, impatient, or bored. More importantly, their nervousness to perform well in mathematics exercises restricted their confidence to try without guidance. For those who had more difficulties, a teacher's prompts, and aids for a transition from easy to difficult questions, made a great difference.

I've always [did bad] at math. [The instructor] is the best math teacher I've ever had. She explains everything good until everyone understands. (AL)

Actually, this course helped me a lot with my math problem. The way the teacher was teaching was very helpful to me. [Anonymous]

Importance of practice: “Practice, practice, practice...”, although it sounds like a cliché, it was found in this study that practice is a critical aspect for mathematics learning of at-risk adult learners. Negative results were identified when they skipped this vital component. For example, those learners who jumped directly to the post-test from the pre-test, before engaging in the online lessons, did not improve their achievement marks or their understanding. The tendency to not fully engage in practice may be due to their nervousness to excel, confusion with the technical environment, lack of self-directed learning, poor reading skills, or old habits of skipping through work. Increased practice with a variety of activities helped them build knowledge. Repetition of foundational skills and knowledge is paramount for these students.

Concerns and Issues

Although our experience showed that CAI has a positive effect on at-risk adult learners in mathematics, the analysis of the field observation data also revealed a number of concerns. This analysis considered the at-risk state of the learners and their use of technology when learning. Concerns from field observations, which were taken into account in the above effective strategies for CAI learning, and the Discussions section follow.

Confusions: Throughout the term, there were a number of times that students were confused with the format, examples, learning objectives, and navigation of the online teacher’s Web site. The following discussion depicts this confusion along with appropriate examples.

Format: When the online material was not consistent with face-to-face curriculum and instruction, students become very confused. For instance, students saw the fraction half with a slanted dash (like this $\frac{1}{2}$) in the teacher’s and external Web pages. However, in the classroom, the teacher wrote the same fraction with a horizontal dash (like this $\frac{1}{2}$). The students thought these were two different fractions. They did not know that both represented the same meaning in a different expression. Their confusion was due to their limited knowledge and experience with mathematics. This confusion caused some anxiety in their use of the Web pages.

Examples: The teacher’s Web pages incorporated various external links to help students learn mathematics concepts. These external sources had a variety of visual examples explaining step-by-step processes and end products in mathematical operations. However, when working with the students early in the term, the instructor found out that some external Web sites’ examples were calculated incorrectly, or the process was presented differently from how they were taught in the face-to-face setting. This confounded students because they had only superficial understanding of the content, and had yet to develop the ability to discern relationships, differences, and errors. At that stage, they were still forming factual knowledge, which could then transform into useable knowledge.

Objectives: Students needed to have clear connections to what they were learning, in relation to life relevancy as well as learning goals. That is, sometimes learning objectives of a lesson or an activity seemed clear to the instructor, but

not to the students. For instance, early in the development of the teacher's Web site, lesson material was briefly displayed without providing the objective and usefulness of each lesson. The teacher thought of the Web site as a continuation of the face-to-face classes, and hence there was no need to repeat the information such as the learning objectives. It was soon realized that the students did not have this clear connection, and they could not see the use of the activities. Consequently, their motivation level was decreased and frustration level was increased, therefore weakening their learning experience.

Navigation: One theme that emerged from the field notes was that the navigation of Web pages is vital. For those at-risk adult learners, they were unfamiliar with the current trends in learning with technology, and lacked confidence. So when they browsed through the Web pages, it was easy for them to get lost. This was also the case even when they had used the Web pages for several weeks, and were getting use to the procedures. In this case, it was critical that the teacher helped, and that guidance and encouragement was available immediately.

Pre- and post-test intimidation: For the purposes of research as well as to improve learning, pre- and post-tests were administered. It was found when students could not perform the pre-tests—a new mathematical procedure—they got frustrated and intimidated by the process. Hence, the pre-test did not serve as a useful way for students to properly plan their learning, as it created anxiety. The teacher reacted by changing the last pre-test to one of predicting and estimating answers rather than finding the exact answer for the problems. Students felt more relaxed and interested in the lesson with this approach.

Reading and content: When a lesson was more complex and had a large amount of reading involved, it was found that learners had difficulties in understanding the lesson's concepts. More so, simply reading brief definitions on Web pages is not enough for them to understand complex concepts. For example, one lesson was about identifying and combining like terms in equations. The combining involved adding and subtracting coefficients with similar terms. This was set up as one lesson and learned in one day. We noticed that these students had trouble comprehending the large amount of text reading on an external Web site, and they were overwhelmed by the complex content presented in the teacher's Web site. They constantly asked help and sought extra explanation from the instructor.

Boringness: As students became more familiar with the mathematics processes and online procedures, they become more confident in their learning. Nonetheless, some more advanced students became bored with the online exercises. Hence, more complex online quizzes and challenging mathematical games were integrated and students enjoyed them, and did very well.

DISCUSSION

The findings of this study highlight some important issues for teaching adult at-risk learners with technology. Do adult at-risk learners improve their level of achievement in mathematics studies by engaging with CAI? Our analysis shows some positive gains in various achievement tests including three paper-based unit tests, and two online quizzes. This suggests that at-risk adult learners benefit academically in some areas with the use of CAI.

For the remaining tests, we found students learning with CAI were doing as well as those learning without technology. This confirms the findings by Nicol and Anderson (2000) that at-risk learners perform just as well with CAI as with conventional instruction, showing that educational technology in the form of CAI does not negatively affect learning. It is worth noting that there was no significant gain between the two groups in the later part of the course. One possible explanation is that these later lessons and tests dealt with more complex ideas and concepts. In the online components, these lessons and tests employed very sophisticated language specific to mathematics. At-risk students with low literacy skills are hindered by their inability to comprehend written language at this level in a CAI environment.

As well, the exit survey results revealed that students hope to use computers more in the future. This was positively correlated with how helpful they found the math Web site in understanding concepts, and how effective they found the interactive quizzes and exercises for learning. Further, access seems to have had a positive effect on students' perception of how much they learned. The more access and use they had of the CAI, whether at school or at home, the more their understanding of math concepts increased. This supports the findings of Lewis (1997) that technology lends towards improved delivery in instruction and thus positively affects students' learning.

The benefits we found that emerged while using CAI include increased confidence and satisfaction with student learning. Both Lewis (1997) and Avitabile (1996) found similar reactions with the integration of technology into learning. That is, they found improvement in student attitude and confidence contributing to enhanced student learning.

In addition, students' knowledge, skill, and ability reflected in face-to-face settings were easily transferable to online environments. There was evidence of reciprocal transferring of skills and knowledge between in-class and online learning. Both mediums helped strengthen student learning, which was evident in their work, understanding, and ability both in class and online. This suggests that the continuity of online and in-class learning helps bridge the possible gap of understanding.

Additionally, having access to the Web site gave those with language barriers, including the Native students, additional resources to learn concepts. They could read explanations, practice, and test their learning in a self-controlled environment as slowly and as often as they needed.

The issues identified in this study include confusion when using Web-based CAI activities, struggle with the level of reading with online content, pre- and post-test intimidation, and possible boredom with material. Both Johnson and Hegarty (2003) and Moll (1997) found similar challenges when using technology with learning-disabled students. For example, they found that students struggle with reading difficulties. As an important note, Jitendra and Xin (1997) suggest that at-risk students should first master basic computer skills to avoid possible technological confusion while learning.

Further, the findings of this research suggest that CAI can be used more effectively when instruction is thoughtfully scaffolded, the tool is used purposefully to

practice mathematics activities, and learning is assisted by a supportive and skilled teacher. Both Nicol and Anderson (2000) and Johnson and Hegarty (2003) saw the benefits of extended practice through the use of technology, and the Learning Disability Association of Canada (1999) encourages scaffolding by providing small sequenced tasks that are well organized, leading to the mastery of skills.

CONCLUSION

The findings of this paper indicate that CAI can be an effective method for at-risk learners, positively affecting their mathematical learning. Our analysis shows some positive gains in various achievement tests as well as increased student confidence and satisfaction with mathematical learning. In addition, CAI provides alternative learning resources that can better address diversity in language abilities, disabilities, skill levels, and learning styles among this population. We recognize that the final grades and some quizzes yielded no significant difference between the two groups, however, the noteworthy gain in other tests and affective variables (such as confidence and attitudes) suggests the potential for CAI for teaching mathematics to at-risk learners.

The most effective strategies found were the building of knowledge through increased practice and learning with online and computer-based lessons. In addition, with the ease of designing scaffolded learning in digital environments and with the presence of continual teacher support, learners overcome learning difficulties, and become more satisfied with their learning.

A crucial Web-based design consideration for struggling learners is the provision of effective modeled cognitive processes. By focusing on appropriate instructional design criteria, at-risk learners using technology can experience learning that addresses their barriers. Educational institutions must consider that these learners need more individualized assistance, and that traditional educational practices have proven ineffective for them. Until the time that a learner develops enough self-confidence, internalizes learning strategies, builds sufficient skills, and forms a higher knowledge base, appropriate and empathetic interventions are essential. This is represented in this study's results from teaching foundational concepts using extensive scaffolding to build knowledge in a supportive and technical environment.

Contributors

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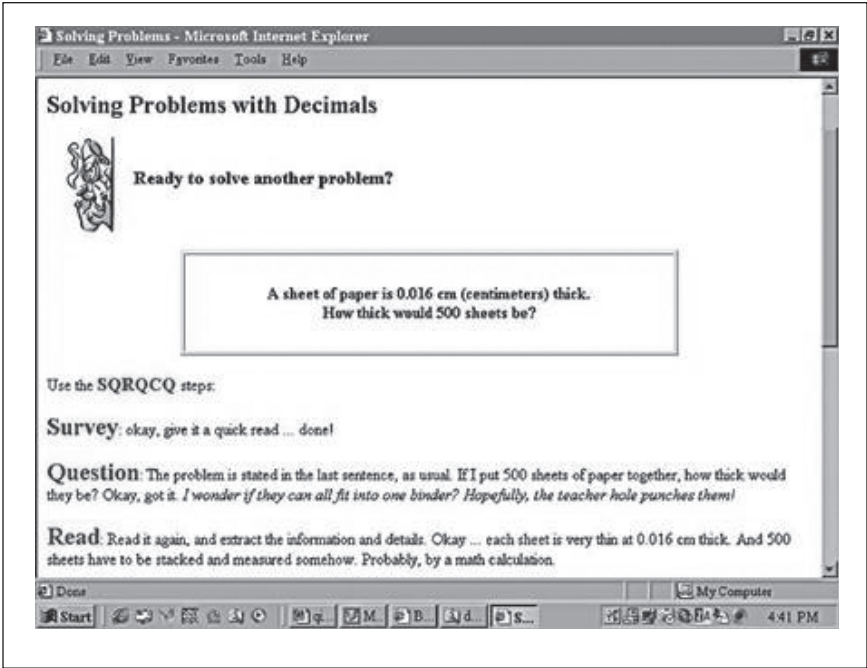
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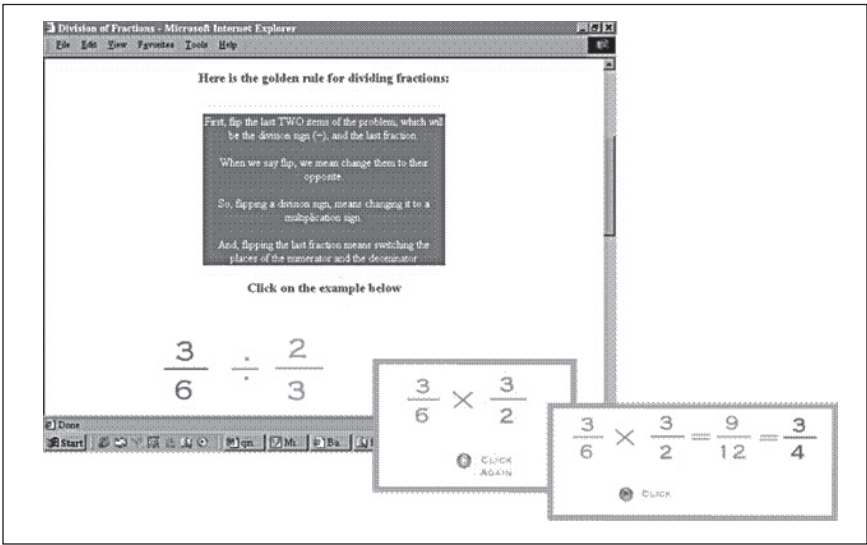
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APPENDIX



Example 1: gradually adjusting the difficulty of the task



Example 2: providing a cognitive tool to supplant the task performance